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Forest Health Protection
Pacific Southwest Region

Date: October 14, 2010
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To: District Ranger, Mt. Hough Ranger District, Plumas National Forest

Subject: Evaluation of stand conditions with respect to forest insects and diseases in the Keddie Ridge Hazardous Fuels Reduction Project (FHP Report NE10-12)

At the request of Ryan Tompkins, Silviculturist, Mt. Hough Ranger District, Bill Woodruff, Forest Health Protection (FHP) plant pathologist, and Danny Cluck, FHP entomologist visited the Keddie Ridge Hazardous Fuels Reduction Project (HFRP) on September 16, 2010. The objective of this visit was to evaluate current stand conditions, determine the impacts of forest insects and diseases on management objectives and discuss proposed alternatives. Recommendations provided in this report will assist in the formulation of silvicultural prescriptions aimed at reducing stand density and increasing resiliency to disturbance events such as fire, insects and diseases. Ryan Tompkins and Alex Yiu, Assistant Silviculturist, accompanied us in the field.

Background

The Keddie Ridge HFRP is located around Indian Valley and the communities of Greenville, Crescent Mills and Taylorsville, CA (T26N, R9E and 10E). The elevation of the project area ranges from 3,600 to 6,500 feet with annual precipitation ranging from 30 – 60 inches (Figure 1). Existing forest types are highly variable within the project area ranging from low elevation, south facing, ponderosa pine (*Pinus ponderosa*) and black oak (*Quercus kelloggii*) stands to higher elevation mixed conifer stands dominated by white fir (*Abies concolor*). Much of the area, however, is comprised of the Sierran mixed-conifer type with various amounts of ponderosa pine, Douglas-fir (*Psuedotsuga menziesii*), Incense cedar (*Calocedrus decurrens*), sugar pine (*Pinus lambertiana*), white fir and black oak. Nearly all stands are overly dense with an abundance of smaller diameter (< 15” dbh) trees. In many stands, this understory is

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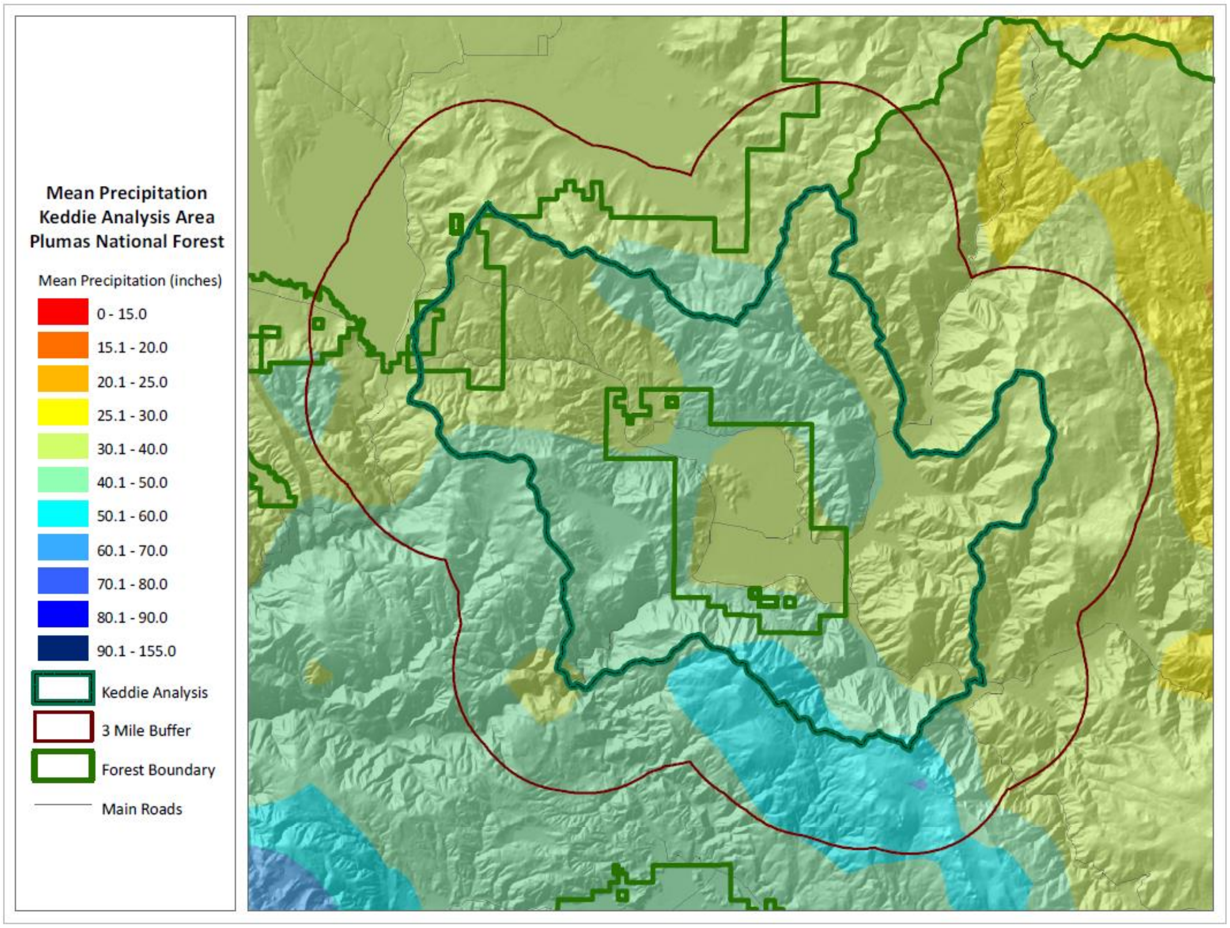

Figure 1. Mean annual precipitation for the Keddie HFRP and surrounding area (map is centered on Indian Valley)

predominantly comprised of shade-tolerant species such as white fir. The management objectives for this project are to create defensible fuel profile zones (DFPZ) with a variable thinning strategy partially based on the PSW General Technical Report 22: *An Ecosystem Management Strategy for Sierran Mixed-Conifer Forests*. Variable thinning would reduce stand density and change species composition to a more sustainable condition by removing trees from all size classes (< 30" dbh), creating gaps and clumps, and removing competition from around old growth trees. Based on current stand conditions, most of the material removed during thinning would be in the < 20"dbh range. This type of treatment would begin to move stands to a more resilient condition that is consistent with Regional ecosystem restoration goals.

Observations

Four distinctive treatment areas were evaluated during this visit: Round Valley (Unit 75) and Greenville (Unit 68), both variations of the Sierran mixed-conifer type, Unit 45, a ponderosa pine stand, and a white fir dominated stand on the crest of Keddie Ridge.

Round Valley (Unit 75)

Very little tree mortality was observed in this Bald Eagle Management Area due to insects and/or diseases. Scattered old growth ponderosa and sugar pine are growing among younger, dense mixed conifer species including white fir, incense cedar and Douglas-fir (Figure 2). Lodgepole pine (*Pinus contorta var. murrayana*) regeneration is also present within portions of the stand.

Figure 2. Mixed conifer overstory with ponderosa pine, sugar pine and white fir.

Figure 3. Fir engraver beetle galleries etched in dead and down white fir.

Fir engraver beetle (*Scolytus ventralis*) caused top-kill and whole tree mortality was observed in white fir. This mortality appears to be closely associated with heterobasidion root disease (*Heterobasidion occidentale*) centers which appear to be present throughout the stand. Evidence of past fir engraver beetle associated mortality is also evident throughout the stand (Figure 3).

Note: *H. occidentale* was formerly referred to as "S-type" annosus root disease (*Heterobasidion annosum*).

Evidence of older western pine beetle (*Dendroctonus brevicomis*) activity was found in a wind damaged ponderosa pine but mortality caused by this bark beetle is generally absent from the stand. However, western pine beetle caused mortality is occurring in adjacent stands and throughout the project area based on FHP aerial detection surveys in 2009 and 2010.

Western gall rust (*Peridermium harknessii*) was observed on lodgepole pine regeneration.

Elytroderma needle cast (*Elytroderma deformans*) is infecting a few ponderosa pines causing needle dieback and branch brooming.

<u>*Greenville (Unit 68)*</u>

Tree mortality is low within this predominantly second growth stand that consists of an extremely dense understory of ~363 TPA (< 10" dbh). A few large diameter (> 30" dbh) sugar pines are also scattered throughout the area.


Figure 4. White pine blister rust canker on young sugar pine.

White pine blister rust (*Cronartium ribicola*) was observed in sugar pine causing branch flagging on overstory trees and top-killing on understory trees (Figure 4).

Red Ring Rot (*Phellinus pini*) was found on the stem of a Douglas-fir as evidenced by numerous conks.

<u>*Ponderosa pine stand (Unit 45)*</u>

This relatively pure stand of ponderosa pine is currently overstocked at ~165 ft^2/acre. Black oak and Douglas-fir are present in low numbers throughout the area.

Group and single-tree mortality, caused by the western pine beetle, was observed throughout the stand.

Western dwarf mistletoe (*Arceuthobium campylopodum*) was also observed in a few ponderosa pines.

<u>*Keddie Ridge white fir stand*</u>

This white fir dominated stand is currently stocked at levels above 220ft^2/acre with a mix of species such as red fir (*Abies magnifica*), sugar pine, Douglas-fir and incense cedar.

Fir engraver beetle activity in true fir, associated with heterobasidion root disease, exists within the stand and is causing top-kill and whole tree mortality.

Discussion and Recommendations

Current tree mortality attributable to insects and/or pathogens is patchy within the project area, and mostly restricted to white fir and ponderosa pine at relatively low levels. However, Forest Health Protection aerial detection surveys (ADS) of the project area have identified an increase in mortality during the past two years (Table 1). Elevated levels of tree mortality in this area, as well as in the rest of the Sierra Nevada range, are strongly associated with periods of below normal precipitation and high stand density. Successive dry years can exacerbate unhealthy stand conditions, such as those that exist within the Keddie Ridge HFRP; resulting in higher levels of bark beetle caused tree mortality. The Palmer Hydrologic Drought Index is also included in Table 1 to show the relationship between drought and tree mortality.

Table 1. Acres, dead trees per acre, total dead trees and Palmer Hydrologic Drought Index (PHDI) by year within and adjacent to the Keddie HFRP as estimated from annual FHP aerial detection surveys.

Year	Acres	Dead Trees/Acre	Total # of Dead Trees	PHDI*
2010	4,450	3.63	16,132	0.14
2009	8,496	2.65	22,535	-2.52
2008	264	2.10	554	-2.71
2007	865	1.15	994	-2.64
2006	46	2.59	119	2.71
2005	4,061	0.94	3,829	0.37
2004	10,207	0.90	9,231	-1.22
2003	63,091	2.46	155,051	-0.54
2002	58,992	2.57	151,375	-2.12
2001	164	1.65	270	-1.58

*Palmer Hydrologic Drought Index for the Sierra Cascade Climate Division obtained from NOAA. PHDI values ranging from -1.00 to -1.99 are considered mild drought conditions, -2.00 to -2.99 are moderate drought conditions and -3.00 to -3.99 are severe drought conditions.

Mapping by the ADS over the past 10 years within and adjacent to the Keddie HFRP reveals many areas where bark beetle caused tree mortality has occurred at elevated levels (Figure 5). Most of this past mortality occurred in white fir growing within the 30 to 40 inch annual precipitation zone. White fir growing within this precipitation zone is considered at a medium risk for bark beetle caused tree mortality based on previous drought periods in northeastern California. Past observations of white fir mortality within the 30 to 40 inch annual precipitation zone during these events averaged 5 – 10%, with some areas experiencing much higher levels.

Figure 5 also depicts many areas where no mortality was mapped during the past 10 years. These areas generally reflect the higher precipitation zones, privately managed timberlands and non-forested lands. However, many forest stands do exist within this “mortality free” zone that are at a high risk to bark beetle caused tree mortality due to overstocked conditions and could experience unacceptable levels of tree mortality in the future. Anticipating future drought events and reducing tree density to levels that are more resilient and sustainable, combined with a shift in species composition away drought intolerant white fir, should reduce the risk of unacceptable levels of tree mortality within the Keddie HFRP.

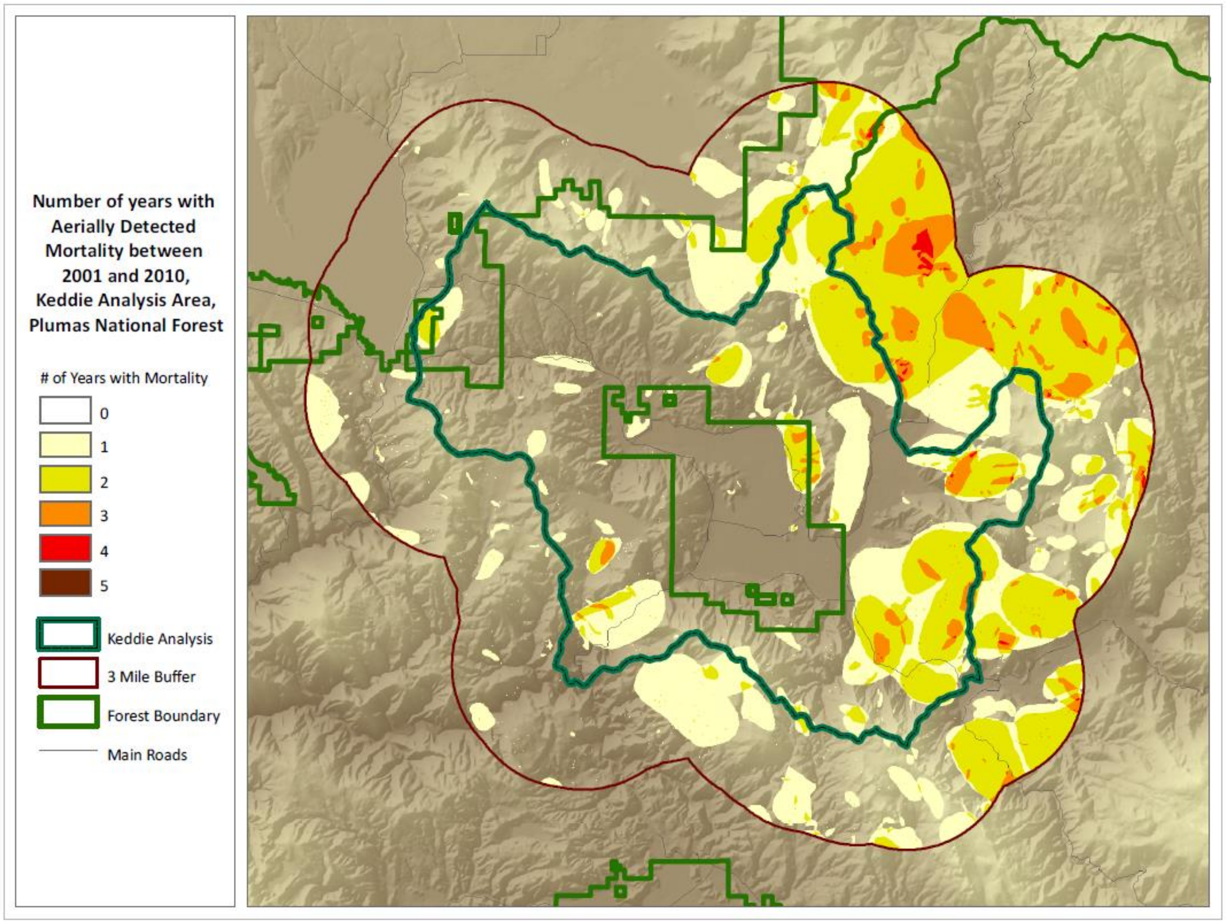

Figure 5. Areas and number of years with mapped tree mortality within and adjacent to the Keddie HFRP (mapped centered on Indian Valley).

Most of the thinning treatments proposed by the District should reduce stand density to a level that significantly lowers the risk of bark beetle caused mortality. In most cases, thinning to a relative density of 25 - 40% (relative to the maximum Stand Density Index, or SDI) for a specific conifer species or for a weighted composition of conifer species will effectively reduce competition for limited water and nutrients and reduce the susceptibility to future bark beetle caused tree mortality. Thinning to this level would also be consistent with past direction from the Regional Forester that suggests designing thinnings to "ensure that density does not exceed an upper limit (for example: 90% of normal basal area, or 60% of maximum stand density index)" and to "design thinnings to ensure that this level will not be reached again for at least 20 years after thinning." (Regional Forester letter, "Conifer Forest Density Management for Multiple Objectives", July 14, 2004). .

When planning thinning treatments, it should be recognized that the target stand density is an average to be applied across the landscape and some variability may be desired. Individual high value trees, such as mature pines and black oaks, should benefit by having the stocking around them reduced to lower levels. Areas of pure or nearly pure ponderosa pine would also benefit from lower stocking levels as well as an increase in species diversity. Allowing for denser tree spacing and pockets of higher canopy cover may be desirable around potential wildlife trees, such as forked and/or broken-topped trees, or on more mesic north-facing slopes. Incorporating

the concepts of GTR 220 will address many of these issues and be consistent with Regional ecosystem restoration goals. Many of these methods are also consistent with past FHP recommendations for thinning in mixed conifer stands and their use is supported for the Keddie Ridge HFRP.

When developing the silvicultural prescriptions for the Keddie HFRP units, the low incidence of dwarf mistletoe, elytroderma disease, red ring rot, western gall rust and the limited bark beetle activity could be addressed by emphasizing infected/infested tree removal and should not keep the District from achieving overall management objectives. High levels of heterobasidion root disease (*H. occidentale*) in white fir, however, need to be considered when determining residual species composition, stand density, and the location of gaps and groups as significant mortality of infected trees may occur during extended drought periods. The presence white pine blister rust is a special situation and is addressed below.

For all thinning operations, it is recommended that a registered borate compound be applied to all freshly cut pine and cedar stumps >14" dbh in order to reduce the chance of new *H. irregulare* (formerly "P-type" annosus root disease) centers being created through harvest activity. However, the treatment of true fir stumps may not be beneficial as all stands appear to have a high level of *H.occidentale* already present.

Sugar pine should be retained as much as possible during any thinning operation in order to preserve genetic diversity, especially white pine blister rust (*Cronartium ribicola*) resistant individuals. White pine blister rust, a non-native pathogen, has continued to weaken and kill this species over most of its range since its introduction into the Pacific Northwest in 1910. Identification and protection of local rust resistant trees for seed collection, if not already occurring, will aid in the future planting of rust resistant seedlings. Planting selected openings created through thinning operations with rust resistant stock would help insure this species persists in the area.

If prescribed fire is used as a follow-up treatment to stand thinning, it may result in unacceptable levels of tree mortality; depending on management objectives. This mortality most often occurs as a direct result of cambium or crown injury to individual trees during the fire. Mature ponderosa, Jeffrey and especially sugar pines are susceptible to lethal basal cambium damage during prescribed burns from the heat that develops in the deep duff and litter that accumulates at their bases. These duff mounds typically burn at a slow rate with lethal temperatures, causing severe injury to the cambium which girdles the trees. To protect individual high-value large diameter pine from lethal cambium damage, raking the duff away from the bases of these trees before burning (within 24" of the bole and down to mineral soil) is recommended.

Stand Specific Recommendations

Round Valley (Unit 75)

The proposed action for the Keddie HFRP allows residual stocking in this unit to be between 120 and 210 ft^2/acre. As long as the ponderosa pine dominated portions of the unit are thinned to the lower end of this basal area range, the treatment should significantly reduce the risk of successful

western pine beetle attacks. Overall, this stand appears to have significantly shifted in species composition from shade intolerant ponderosa and sugar pine to shade tolerant white fir in the absence of fire. Managing overall stand density more for the ponderosa pine component would be a prudent strategy to limit future bark beetle caused mortality. Potentially, more 20 – 30” dbh white fir could be removed to meet lower stocking objectives, especially considering the presence of *H. occidentale* within the stand. If canopy cover requirements do not allow for an effective reduction in stand density that increases the health and vigor of residual trees, the risk for bark beetle caused mortality will remain high, especially during prolonged periods of drought. Failure to reduce the risk of bark beetle caused mortality could result in the loss of large diameter pines and reduced nesting opportunities for bald eagles. If overall stand density cannot be further reduced due to canopy cover restrictions, more trees should be removed around large diameter pine species and pine dominated portions of the stand balanced by the retention of higher densities in more mixed conifer areas.

<u>Greenville (Unit 68)</u>

The thinning treatments planned by the District should be sufficient to effectively reduce the risk of bark beetle caused mortality. Consideration may be given to retaining clumps of black oak and increasing spacing around large diameter sugar pines.

<u>Ponderosa pine stand (Unit 45)</u>

Previous thinning and burning projects in this stand have left a relatively open forest condition with few surface and ladder fuels. However, stocking remains at levels above what is considered sustainable for pure ponderosa pine stands. As a result, elevated levels of western pine beetle caused tree mortality can be found throughout the area. The District should consider using the bark beetle limiting SDI of 365 as a basis for thinning prescriptions. SDI 365 is considered the upper management zone above which bark beetle outbreaks are likely to occur and SDI 230 is considered the threshold for the zone of imminent bark beetle caused mortality. Within this zone, endemic populations kill a few trees but net growth is still positive (Oliver 1995). Planning thinning treatments that result in stocking levels well below SDI 230 would greatly reduce the risk of bark beetle caused mortality in this area.

<u>Keddie Ridge white fir stand</u>

Treatments in this area should focus on increasing diversity through the removal of white fir in favor of other conifer species. Retaining high numbers of white fir in this area does not create a resilient stand condition and will likely result in excessive tree mortality and fuel build up. This area is a key defensive fuel profile zone (DFPZ) and the abundance of *H. occidentale* infected white fir leaves this stand vulnerable to significant tree mortality during extended drought periods. Furthermore, the maintenance of this DFPZ will rely heavily on prescribed fire which could result in additional injury and mortality to the white fir component. The District should consider removing small groups of *H. occidentale* infected white fir to facilitate the planting and/or natural regeneration of sugar pine, ponderosa pine, Jeffrey pine, Douglas-fir and incense cedar.

If you have any questions regarding this report and/or need additional information please contact Danny Cluck at 530-252-6431.

/s/ Danny Cluck

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Insect and Disease Information

Fir Engraver

The fir engraver attacks red and white fir in California. Fir engraver adults and developing broods kill true firs by mining the cambium, phloem, and outer sapwood of the bole, thereby girdling the tree. Trees greater that 4” in diameter are attacked and often killed in a single season. Many trees, weakened through successive attacks, die slowly over a period of years. Others may survive attack as evidenced by old spike-topped fir and trees with individual branch mortality. Although many other species of bark beetles cannot develop successful broods without killing the tree, the fir engraver beetle is able to attack and establish broods when only a portion of the cambium area has been killed.

Evidence of Attack

Fir engravers bore entrance holes along the main stem, usually in areas that are > 4” in diameter. Reddish-brown or white boring dust may be seen along the trunk in bark crevices and in spider webs. Some pitch streamers may be indicative of fir engraver attacks; however, true firs are known to stream pitch for various reasons and there is not clear evidence that pitch streamers indicate subsequent tree mortality or successful attack. Resin canals and pockets in the cortex of the bark are part of the trees defense mechanism. Beetle galleries that contact these structures almost always fail to produce larval galleries as the adults invariably abandon the attack. Pitch tubes, often formed when bark beetles attack pine, are not produced on firs.

Adults excavate horizontal galleries that engrave the sapwood; the larval galleries extend at right angles along the grain. Attacks in the crown may girdle branches resulting in individual branch mortality or "flagging". Numerous attacks over part or the entire bole may kill the upper portion of the crown or the entire tree. A healthy tree can recover if sufficient areas of cambium remain and top-killed trees can produce new leaders. The fir engraver is frequently associated with the roundheaded fir borer and the fir flatheaded borer.

Life Stages and Development

In the summer, adults emerge and attack new host trees. The female enters the tree first followed by the male. Eggs are laid in niches on either side of the gallery. Adult beetles carry the brown staining fungi, *Trichosporium symbioticum*, into the tree that causes a yellowish-brown discoloration around the gallery. The larvae mine straight up and down, perpendicular to the egg gallery. Winter is commonly spent in the larval stage, with pupation occurring in early spring. In most locations, the fir engraver completes its life cycle in 1 year, however at higher elevations 2 years may be required.

Conditions Affecting Outbreaks

Fir engravers bore into any member of the host species on which they land but establish successful galleries only in those that have little or no resistance to attack. Populations of less aggressive species like fir engraver are likely to wax and wane in direct relationship to the stresses of their hosts. Drought conditions often result in widespread fir mortality; however, attempting to determine when outbreaks will occur is difficult. Lowered resistance of trees appears to be a contributing factor. Overstocking and the increased presence of fir on sites that were once occupied by pine species may also contribute to higher than normal levels of fir mortality. Several insect predators, parasites and woodpeckers are commonly associated with the fir engraver and may help in control of populations at endemic levels.

Western Pine Beetle

The western pine beetle, *Dendroctonus brevicomis*, has been intensivly studied and has proven to be an important factor in the ecology and management of ponderosa pine thoughout the range of the host species (Miller and Keen 1960). This insect breeds in the main bole of living ponderosa pine larger than about 8 inches DBH. Normally it breeds in trees weakened by drought, overstocking, root disease, dwarf mistletoe or fire. Adult beetles emerge and attack trees continuously from spring through fall. Depending on the latidude and elevation, there can be from one to four generations per year.

Evidence of Attack

Initial attacks are made about mid-bole and subsequent attacks fill in above and below. Pitch tubes are formed on the tree trunk around the entry holes. Successful pitch tubes are red-brown masses of resin and boring dust. Relativly few, widely scattered white pitch tubes usually indicate that the attacks were not successful and that the tree should survive. Pheremones released during a successful attack attract other conspecifics. Attracted beetles may then spill over into nearby apparently healthy trees and overwhelm the tree with sheer numbers.

Life Stages and Development

These beetles pass thorugh the egg, larval, pupal and adult stages during a life cycle that varies in length dependent primarily on temperature. Adults bore a sinuous gallery pattern in the phloem and the female lays eggs in niches along the sides of the gallery. The larvae are small white grubs that first feed in the phloem then mine into the middle bark where they complete most of their development. Bluestain fungi inoculates the tree during successful attacks, blocking trachids and vessicles which contribute to the rapid tree mortality associated with bark beetle attacks.

Conditions affecting Outbreaks

Outbreaks of western pine beetle have been observed, and surveys made, in pine regions of the Westsince 1899 (Hopkins 1899; cited in Miller and Keen 1960). An insect survey completed in 1917 in northern California indicated that over 25 million board feet of pine timber had been killed by bark beetles.Information from surveys conducted in the 1930's indicated enormous losses attributed to the western pine beetle around that time. During the 1930's outbreak, most of the mortality occurred in stands of mature or overmature trees of poor vigor (Miller and Keen 1960). Group kills do not typically continue to increase in size though successive beetle generation as is typical with Mountain Pine Beetle and Jeffreay Pine Beetle. Rather, observations indicate that emerging beetles tend to leave the group kill area to initiate new attacks elsewhere.

The availability of suitable host material is a key condition influencing western pine beetle outbreaks. In northeastern California, drought stress may be the key condition influencing western pine beetle outbreaks. When healthy trees undergo a sudden and sever mositure stress populations of western pine beetle are likely to increase. Healthy trees ordinarly produce abundant resin, which pitch out attacking beetles, but when deprived of moisture, stressed treese cannot produce sufficent resin to to resist the attack. Any condition that results in ecessive demand for moisture, such as inter-tree competion, competing vegetation, or protracted drought periods; or any condition that reduces the abiltiy of the roots to supply water to the tree, such as mechanical damage, root disease or soil compaction, can cause mositure stress and increase susceptibility to attack by the western pine beetle. Woodpeckers, predatious beetles, and low temperatures act as natural control agents when beetle populations are low (endemic populations).

Heterobasidion Root Disease

Heterobasidion spp. is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridentata*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all National Forests in California, with incidence particularly high on true fir in northern California, in the eastside pine type forests, and in southern California recreation areas.

Heterobasidion root disease is one of the most important conifer diseases in Region 5. Current estimates are that the disease infests about 2 million acres of commercial forestland in California, resulting in an annual volume loss of 19 million cubic feet. Other potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of the site for future production, and depletion of vegetative cover and increased probability of tree failure and hazard in recreation areas.

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers are initiated when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds, or occasionally, through roots of stumps in the absence of surface colonization. From the infected stump surface, the fungus grows down into the roots and then spreads via root-to-root contact to adjacent live trees, resulting in the formation of large disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but more frequently is confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss.

Heterobasidion root disease in western North America is caused by two species: *Heterobasidion occidentalis* (also called the 'S' type) and *H. irregularis* (also called the 'P' type). These two species of *Heterobasidion* have major differences in host specificity. *H. irregularis* (‘P’ type) is pathogenic on ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense cedar, western juniper, pinyon, and manzanita. *H. occidentalis* (‘S’ type) is pathogenic on true fir, spruce and giant sequoia. This host specificity is not apparent in isolates from stumps; with *H. occidentalis* being recovered from both pine and true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers established near these stumps often die shortly after their roots contact infected roots in the soil.

Dwarf Mistletoe

Dwarf mistletoes (Arceuthobium spp.) are parasitic, flowering plants that can only survive on living conifers in the Pinaceae. They obtain most of their nutrients and all of their water and minerals from their hosts.

Dwarf mistletoes spread by means of seed. In the fall the fruit ripen and fall from the aerial shoots. The seeds are forcibly discharged. The seed is covered with a sticky substance and adheres to whatever it contacts. When a seed lands in a host tree crown, it usually sticks to a needle or twig, where it remains throughout the winter. The following spring the seed germinates and penetrates the twig at the base of the needle. For the next 2-4 years, the parasite grows within the host tissues,

developing a root-like system within the inner bark and outer sapwood, and causing the twig or branch to swell. Aerial shoots then develop and bear seed in another 2-4 years.

Dispersal of dwarf mistletoe seeds is limited to the distance the seeds travel after being discharged. From overstory to understory, this is usually 20 to 60 feet, but wind may carry them as far as 100 feet from the source. A rule of thumb is that the seeds can travel a horizontal distance equal to the height of the highest plant in an infected tree. There is some evidence that long distance spread of dwarf mistletoe is occassionaly vectored by birds and animals.

Vertical spread within tree crowns of most dwarf mistletoes is limited to less than one foot per year because of foliage density. Because of the thin crowns of gray pine, however, the vertical rate of spread has been measured as being greater than 2 feet per year. This rate of spread equalled or exceeded the rate of height growth of infected trees.

Dwarf mistletoes are easy to identify because they are generally exposed to view within a tree's crown. Signs of infection include the yellow-green to orange mistletoe plants, basal cups on a branch or stem where the plants were attached and detached plants on the ground beneath an infected tree. Symptoms include spindle-shaped branch swellings, witches' brooms in the lower crown, and bole swellings.

White pine blister rust

White pine blister rust is caused by Cronartium ribicola an obligate parasite that attacks 5-needled pines and several species of Ribes spp. The fungus needs the two alternate hosts to survive, spending part of its life on 5-needled pines and the other on Ribes spp. The disease occurs throughout the range of sugar pine to the southern Sierra Nevada, but has not been reported further south. Infection of pines results in cankers on branches and main stems, branch mortality, top kill, and tree mortality.

Spores (aeciospores) produced by the fungus in the spring on pine bole or branch cankers are wind-disseminated to Ribes spp. where they infect the leaves. Spores (urediospores) produced in orange pustules on the underside of the leaves reinfect other Ribes spp. throughout the summer, resulting in an intensification of the rust. A telial spore stage forms on Ribes spp. leaves in the fall. Teliospores germinate in place to produce spores (sporida) which are wind-disseminated to pines and infect current year needles. Following infection, the fungus grows from the needle into the branch and forms a canker. After 2 or 3 years, spores are produced on the cankers and are spread to Ribes spp. to continue the cycle. Although blister rust may spread hundreds of miles from pines to Ribes spp., its spread from Ribes spp. back to pines is usually limited to a few hundred feet.

Branch cankers continue to enlarge as the fungus invades additional tissues and moves toward the bole. Branch cankers within 24 inches of the bole will eventually form bole cankers. Bole cankers result in girdling and death of the tree above the canker. Cankers that have margins more than 24 inches from the main bole are unlikely to reach the bole and only branch flagging will result.